**Work**

| | | |
|---|---|---|
| 2016 | **3.** A constant force $\mathbf{F} = (2\mathbf{i} + 3\mathbf{j})$ N acts on a particle as it moves in a straight line from point A to point B with position vectors $(-3\mathbf{i} + \mathbf{j})$ metres and $(6\mathbf{i} + 4\mathbf{j})$ metres respectively.<br>Calculate the work done by the force. | **3** |
| 2013 | **A3.** A particle of mass 3 kilograms moves under the action of its own weight and a constant force $\mathbf{F} = (3\boldsymbol{i} + 5{\cdot}4\boldsymbol{j})$ where $\boldsymbol{i}$ and $\boldsymbol{j}$ are unit vectors in the horizontal and vertical directions respectively.<br>Initially the particle has velocity $(2\boldsymbol{i} - \boldsymbol{j})$ m s$^{-1}$ as it passes through a point $A$. The particle passes through $B$ after 4 seconds. Find the work done to move the particle from $A$ to $B$. | **5** |

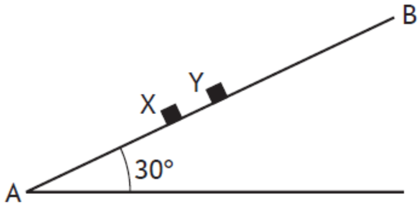
**Conservation of Momentum and Energy**

| | | |
|---|---|---|
| 2006 | **A5.** A railway truck of mass $3m$ kilograms travelling at $u$ m s$^{-1}$ along a straight horizontal track, collides and couples with a stationary truck of mass $m$ kilograms. Due to the action of a constant resistive force of magnitude $R$ newtons, the two trucks come to rest $T$ seconds after the collision.<br>(*a*) Determine an expression for $R$ in terms of $m$, $u$ and $T$. **4**<br>(*b*) Find an expression, in terms of $m$ and $u$, for the work done by $R$ in bringing the trucks to rest. | **3** |
| 2008 (A10) & 2016 EX | **16.** Ice-dancers, Alice and Bob, are skating on a smooth ice rink.<br>• Alice has mass $m_A$ kg and is moving with a constant velocity $(U\mathbf{i})$ms$^{-1}$ and<br>• Bob has mass $m_B$ kg and is moving with a constant velocity $(U\mathbf{j})$ms$^{-1}$,<br>where **i** and **j** are the unit vectors in the direction of the $x$ and $y$ axes respectively.<br>The dancers collide and subsequently move off together with speed $V$ ms$^{-1}$ in a direction which makes an angle $\theta$ with the $x$-axis.<br>(a) Use conservation of momentum to show that<br>$\tan\theta = \frac{m_B}{m_A}$ and $V^2 = \frac{(m_A{}^2 + m_B{}^2)U^2}{(m_A + m_B)^2}$ **5**<br>(b) Given that $\tan\theta = 2$, find an expression for the kinetic energy lost in the collision in terms of $m_A$ and $U$. | **3** |

2017

**8.** Two particles, X and Y, have masses of 0·2 kg and 0·5 kg respectively.

They are moving up a smooth plane AB, inclined at 30° to the horizontal as shown in the diagram.



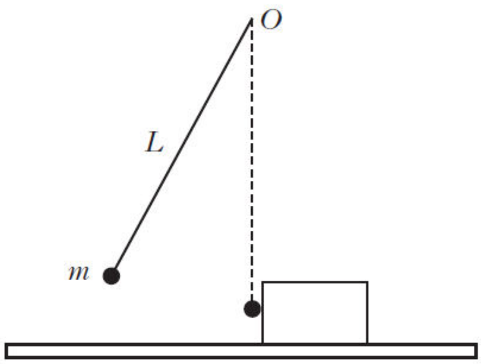

The particles collide 3·5 metres from B when X is moving with a speed of $6\,\mathrm{m\,s^{-1}}$ and Y is moving with a speed of $3\,\mathrm{m\,s^{-1}}$.

This collision causes X to come instantaneously to rest while Y continues to travel up the slope.

Show that in the subsequent motion, Y comes to rest before reaching B. **6**

2012

**A7.** A ball of mass $m$ kg is suspended from a fixed point $O$ by a light, inextensible string of length $L$ metres. The ball is released when the string makes an angle of 45° to the downward vertical and strikes a stationary block of mass $M$ kg horizontally. The block rests on a smooth horizontal surface, as shown in the diagram.




When the ball hits the block, its speed is $u\,\mathrm{m\,s^{-1}}$. The ball then rebounds with speed $v\,\mathrm{m\,s^{-1}}$ and comes to rest when the string makes an angle of 30° to the vertical. Show that

$$u = \sqrt{gL\left(2-\sqrt{2}\right)} \qquad \text{and} \qquad v = \sqrt{gL\left(2-\sqrt{3}\right)}.$$ **4**

The block moves to the right with an initial speed $V\,\mathrm{m\,s^{-1}}$. Show that

$$V = k\frac{m}{M}\sqrt{gL}$$

and state the value of $k$. **3**

**Work/Energy Principle**

| | | |
|---|---|---|
| 2005 SP | **1.** A body of mass 4 kg starts from rest at the origin and moves in a straight line until it is again at rest. Its velocity, in $m\,s^{-1}$, after $t$ seconds is given by $2t(3-\sqrt{t})\,\mathbf{i}$, where $\mathbf{i}$ is the unit vector in the direction of motion. Find the maximum speed of the body and the work done in reaching this maximum speed. | **5** |
| 2014 | **A3.** A car of mass 700 kg is at rest on a horizontal plane when it is acted on by a force $(3000-15x)\mathbf{i}$ N where $x$ is the displacement in metres. There is a constant frictional force of 500 N opposing motion.<br>When $x = 200$ find<br>(i) the total work done on the car; | 2 |
| | (ii) the speed of the car. | 2 |
| 2016 SP | **8.** A stone of mass 0·25 kg moves along a smooth horizontal surface. It passes a fixed point O with a velocity of $3\mathbf{i}\,m\,s^{-1}$. When it is at a distance $x$ metres from O, a force of magnitude $(2\sin x+5)\mathbf{i}$ N acts on it along the line of movement.<br>(a) Calculate the work done by the force in moving the stone 3 metres beyond O. | **2** |
| | (b) Find the speed of the stone at this point. | **2** |
| 2017 | **9.** A body of mass 20 kg is moving along a rough horizontal surface with speed $12\,m\,s^{-1}$. As it passes through a point P, a horizontal force $F=\left(249-50\sqrt{x}\right)$ newtons is applied, where $x$ metres is the displacement of the body from P.<br>Given that the coefficient of friction between the body and the surface is 0·25:<br>(a) find the work done on the body in the first 10 metres of its motion from P | **4** |
| | (b) find the speed of the body after travelling 10 metres from P. | **2** |
| 2005 | **A7.** A particle of mass 2 kg is accelerated horizontally from rest at a point $O$ by a force $8t\mathbf{i}$, whose magnitude is measured in newtons and where $\mathbf{i}$ is the unit vector in the direction of motion and $t$ seconds is the time from the start of the motion.<br>*(a)* Find the velocity, $\mathbf{v}$, of the particle as a function of time $t$. | **2** |
| | *(b)* Calculate the work done on the particle in the first second of the motion. | **3** |
| 2011 | **A6.** A particle with mass 0·25 kg moves along a straight line. Its velocity $\mathbf{v}$ is given by<br>$$\mathbf{v} = 8\,(1-e^{-2t})\mathbf{i}$$<br>where $\mathbf{i}$ is a unit vector in the $Ox$ direction of a rectangular coordinate system with origin $O$. The time $t$ is measured in seconds and the speed is measured in metres per second.<br>Obtain an expression for the force acting on the particle at time $t$. | **2** |
| | Show that the work done by this force during the time interval $0 \le t \le 1$ is given by<br>$$32\int_0^1 (e^{-2t}-e^{-4t})\,dt \text{ joules},$$<br>and hence calculate this value. | **4** |

2015(A8) & 2016 EX

**12.** A particle P of mass 3 kg falls from rest under gravity. Throughout its motion, it experiences a resistance of $0\cdot25v^2$ newtons per unit mass, where $v$ is the speed in metres per second at time $t$.

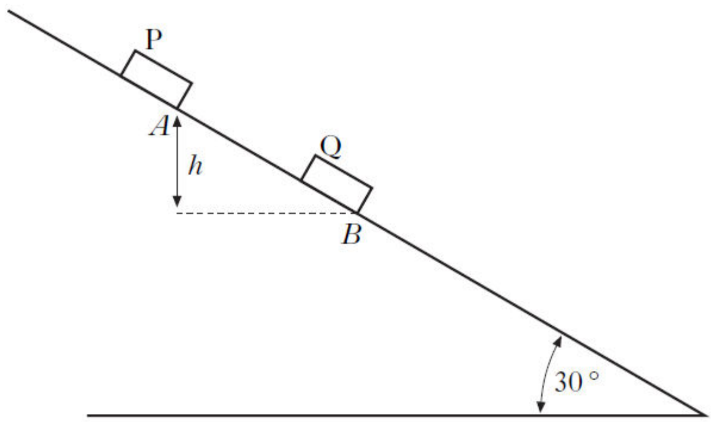
(a) Calculate the distance travelled by the body in reaching a speed of $5\ \text{ms}^{-1}$. **5**

A second particle Q, of mass 5 kg, starts from rest at the origin and moves in a horizontal straight line with acceleration $2t\,\mathbf{i}\ \text{m s}^{-2}$, where $t$ is the time in seconds from the start of the motion and $\mathbf{i}$ is the unit vector in the direction of motion.

(b) Given that the work done by the total force acting on Q during the first $k$ seconds is equal to that done by the particle P in reaching its speed of $5\ \text{m s}^{-1}$, calculate the value of $k$. **5**

2004

**C6.** The diagram shows a ramp, inclined at 30° to the horizontal, which has a smooth section above $B$ and a rough section below $B$. Identical blocks, P and Q, each has weight $W$ newtons. Block Q is stationary at $B$, held by friction, and block P is held at rest at $A$. Block P is a vertical height of $h$ metres above block Q (where the dimensions of the blocks should be ignored).




When block P is released, it slides down the ramp colliding and coupling with block Q. The combined blocks then move down the rough section of the ramp, coming to rest at a vertical height $\frac{1}{2}h$ metres below $B$.

(i) Find, in terms of $g$ and $h$, the speed of the combined block immediately after the collision. **3**

(ii) Using the work/energy principle, show that the constant frictional force acting on the combined block whilst it is moving has magnitude $\frac{3}{2}W$ newtons. **4**